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Regional Differences in the Stochastic Frontiers of Small-Scale Dairy Farmers Assisted by Technical Support in Brazil

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Extended Abstract:

Cow's milk is an important food in the human diet (including in Brazil). In 2023, Brazil was the fifth-largest global producer of this product (ranking below the USA, India, China, and Russia) and accounted for 4.45% of the global milk production. However, the average productivity of dairy cattle farming in Brazil is significantly lower than that of other major milk-producing countries. In 2017, the last year for which there was an Agricultural Census in Brazil, productivity was 2,621 liters/cow/year, while it reached 10,393 liters/cow/year in the USA and 4,340 liters/cow/year in China (according to USDA data). Argentina, Brazil's neighboring country to the south, and the 9th largest world milk producer at the world, achieved a productivity of 6,034 liters/cow/year in 2017. These figures show how important is Brazil to improve its dairy cattle farming. Milk production was present, in 2017, in 1,176,295 agricultural establishments in Brazil (according to the Brazilian Agricultural Census), representing 23.2% of all farms in the country. Productivity varies significantly among the five macro-regions of Brazil, reaching, on average, in 2017, 4,022 liters/cow/year in the South Region, 2,820 liters/cow/year in the Southeast Region, 2,219 liters/cow/year in the Central-West Region, 1,679 liters/cow/year in the Northeast Region, and 1,369 liters/cow/year in the North Region. There was a 194% productivity difference between the South and North regions in 2017. However, certain areas within Brazil achieve international productivity patterns in dairy cattle farming, particularly in the state of Rio Grande do Sul, which borders Argentina. This demonstrates that the country holds the technology necessary (whether in terms of cattle breeds, feeding, and/or animal handling) to achieve higher productivity levels in dairy farming. One way to disseminate this technology is through rural extension services. Over time, Brazil has implemented various rural extension policies, including specific programs for dairy farming. Among these, and currently operating in the third decade of the 21st century, is SENAR's Technical and Managerial Assistance Program (ATeG). This program supports small producers across Brazil for a period of 24 months, aiming to transfer the best technology in dairy farming. Despite this, some regional structural differences in the country raise doubts about whether technical assistance alone can lead to higher productivity levels and greater homogeneity in technological standards for dairy farming across regions. At a minimum, the following questions arise: Do regional differences in land endowment, capital availability, culture, and schooling education among milk producers lead to distinct technological and technical efficiency levels, even among farmers assisted by ATeG-SENAR? Does estimating a single aggregated production function for Brazil and calculating a single technical efficiency score unveil regional differences in producers' technological levels, even if they receive technical assistance? To address these questions, this study aims to estimate stochastic production functions using the Cobb-Douglas formulation for small dairy producers assisted by the ATeG-SENAR program and to highlight the differences in their Stochastic Production Frontiers and technical efficiency levels. Different data aggregations will be performed: first, all producers in the sample will be considered without regional distinctions, and in sequence the Stochastic Production Frontier (SPF) model will be re-estimated by grouping producers according to their

regions (Brazil has five regions). This approach aims to emphasize that global estimates of Stochastic Production Frontiers and Technical Efficiency levels, without considering regional particularities, may obscure the importance of regional policies that seek to equalize factor endowment and education levels across regions, which would enable a more homogeneous dairy activity across Brazilian territory. Since cow's milk production is accompanied by methane (CH_4) emissions, which are inevitable due to the digestion process of cows, it is also necessary to consider these emissions in the production function. Methane emissions can be considered as an environmental input in milk production, separated from land, capital, and labor, which are also used in the production process. Additionally, in Brazil, farming expenses on feed and medications must also be accounted as explanatory variables at SPF. Therefore, this study considers a stochastic production function in which both traditional production factors (such as land, labor, and capital) and methane emissions are treated as inputs. Moreover, the estimation of the Stochastic Production Frontier incorporates elements that explain the technical inefficiency of milk producers. The estimations are based on individual data from producers assisted by the ATeG-SENAR program for the year 2021. A total of 4,767 milk producers were included in our regressions. Six Stochastic Production Frontiers were estimated, and technical efficiency levels were calculated based on these, as the data were initially analyzed collectively for all of Brazil and subsequently grouped by region, with the SPF models re-estimated. The dependent variable in the SPF estimation is the quantity of cow's milk produced, while the explanatory variables include: (1) total farm area, (2) labor expenses (personnel), (3) expenses on supplementary feed (including salt and feed), (4) total capital (excluding land), (5) methane emissions, and (6) medication expenses. Explanatory variables for technical inefficiency include: (a) the age of the farm manager in 2021, (b) the educational level of the farm manager, and (c) the duration of ATeG assistance. The SPF estimates, using the natural logarithm of the aforementioned variables and disaggregated by region, yielded distinct coefficients associated with these two groups of variables, differing in both magnitude and statistical significance. For example, the coefficient associated with labor was 0.1365045 when considering all producers collectively without regional distinctions (the so-called "SPF-Brazil"). However, these coefficients were 0.2077253, 0.117250, 0.175666, 0.135854, and 0.1167291, respectively, for the SPFs estimated separately for the North, Northeast, Southeast, South, and Central-West regions (all of which were statistically significant at the 1% level). A difference of 78% was observed between the minimum and maximum values of this coefficient across the country's regions. Differences were also found in the coefficients associated with other variables used in the SPF estimations. When estimating a single SPF for all of Brazil, the technical efficiency of dairy farmers was 0.789. However, when calculated separately by region, the technical efficiency scores were 0.754, 0.782, 0.745, 0.857, and 0.803 for the North, Northeast, Southeast, South, and Central-West regions, respectively. These results suggest that when estimating stochastic efficiency frontiers for all of Brazil, producer regional differences should be accounted for. This can be done by including regional dummy variables in the SPF model or by estimating a metafrontier production function. Furthermore, regional issues should also be considered when designing rural extension policies aimed at disseminating modern dairy production technologies among Brazilian milk producers. However, the last two points remain as suggestions for future research.

Keywords: dairy cattle farming, technical efficiency, stochastic frontier, regional differences.